Living with a catastrophe at the cost of life: Illegal and Risky settlement on the hill slope in Chattogram city

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Abstract

After landslides in 2007 and 2017, causing 127 and 160 deaths, respectively, the landslide hazard became a focus at the local and national levels. Chattogram is among the most vulnerable cities in Bangladesh. From 2000 to 2018, around 367 landslides occurred, with 204 resulting in fatalities and injuries. Over 500,000 impoverished people live in risky foothill areas, often ignoring the threat of landslides. Easy access to jobs, low rent and abundant hills have driven the growth of illegal settlements. Hill cutting for unauthorized settlements has harmed the hill ecosystem in CMA, obstructing drainage systems and increasing soil erosion and landslide risk. Historical evidence indicates that landslides have caused significant deaths and property damage. Sustainable measures are essential to mitigate landslide disasters.

Various mitigation approaches can reduce the intensity and frequency of landslides. A technical committee formed after 2007 recommended two policies: structural mitigation and relocation. This study aims to identify landslide causes and suggest sustainable solutions to reduce vulnerability in Chattogram. The study will clarify loss reduction strategies and driving factors, assisting policymakers in implementing long-term mitigation for future landslides.

Keywords: Catastrophic events, landslide, urbanization, illegal settlement, structural mitigation, re-location.

Introduction

Chattagram, Bangladesh's second prominent city and a port city, is rapidly growing without proper planning. Due to rapid urbanization, the city's morphology is altering, disrupting natural topography and landscapes by converting them into infrastructure such as settlements, roads and industries. Since 1990, many informal settlements have illegally developed on unused hills belonging to both Government and non-government entities in Chittagong[21]. These land-use changes have compromised the stability of the hills, impacting hydro-morphological characteristics such as infiltration, runoff and rainfall partitioning.

Consequently, rainfall-induced landslides are occurring frequently in Chittagong. The study indicates that landslides and land-use changes in hilly areas are strongly interrelated. Unplanned urbanization escalates population pressure in the city centre and settlements encroach into hilly regions. Most of these settlements are illegal and informal, devastating the natural topography of the hills. The physical survey found that many poor migrants reside in these settlements. Mediators illegally occupy the hills to build settlements for the urban underprivileged people altering the hill slopes and toes. Despite the known landslide risk, urban low-income communities continue to inhabit these areas and become increasingly vulnerable to landslides.

The investigation into landslide history reveals that Chittagong is susceptible to catastrophic landslides. Over 500,000 individuals live in informal settlements on the hills or at their foot, making them susceptible to landslides[21,22]. According to the Department of Disaster Management, from 1999 to 2012, 260 people died and significant damage occurred to houses and properties in informal settlements within Chittagong's hilly areas. In 2007, 127 people perished due to heavy rainfall-induced landslides. The hotspots were Lalkhan Bazar, Motijharna, Tankir Pahar, Batali hill, Akber Shah, Lebu Bagan and Pahartali. Three additional landslides occurred on June 17, 2013, resulting in at least 20 fatalities. Another landslide at Batali hill in Tiger Pass/Lalkhan bazar killed 17 people on July 1, 2011. The study highlights that extreme rainfall over a short period, deforestation for settlement and unauthorized development work are the primary causes of the recent landslides.

The settlement situation in the hilly areas is alarming. If encroachment continues, Chittagong will become increasingly hazardous, with unlivable slums developing in its centre. To assess the city's projected susceptibility, it is essential to identify the reasons behind the land cover changes in the hills and the phenomenon of landslides. The study has identified a significant gap between the actual situation and the necessary actions that authorities took to ensure the safety of poor urban settlers in the hilly areas.

This research focuses on the Batali hill and Motijharna areas to determine landslide-prone zones in the CMA and develop appropriate disaster risk reduction strategies. Considering these facts, this study aims to assess the causes and consequences of landslides and explore mitigation approaches to reduce vulnerability in the study areas of Chittagong city.

The frequency, number and devastation of landslide events in Bangladesh are increasing. In a research study, Neegar Sultana compiled the "Bangladesh Landslide Database (BDLS- DAT)" from 2000 to 2018, detailing the causes and casualties of landslides. The study identified that 367 landslide events occurred in Bangladesh from 2000 to 2018. Of these, 204 were devastating, resulting in significant

fatalities and injuries. The highest incidence of landslides was noted in Chattogram (65 events, 31. 90%) followed by Cox's bazar (63 events, 30. 90%), Bandarban (31 events, 15. 20%) and Rangamati (17 events, 8. 30%). Regarding fatalities, the most significant number of deaths was recorded in Chattogram (279 fatalities, 31.90. 4%), followed by Cox's bazar (179 deaths, 24. 24.6%), Rangamati (110 fatalities, 15. 1%) and Bandarban (91 deaths, 12. 5%).

Unplanned urbanization is compelling disadvantaged groups, primarily migrants, to inhabit the hilly regions of Chattogram city, consequently transforming the land cover. These land cover alterations contribute to landslides, precipitated by erratic rainfall, including seasonal monsoon rains and unprecedented rainfall due to cyclones or depressions, exacerbating the situation. A significant concern is the insufficient capacity of residents and local authorities to address this disaster effectively. Illegal settlements, expanding industries, road construction and residential developments compromise hilly regions. Numerous hills in Chattogram City have already been obliterated and the remaining hills are predominantly disturbed by human activities. Individuals residing on hilltops, slopes and near the base of hills are at heightened risk of landslides triggered by rainfall. According to the Divisional Hill Management Committee, approximately 10,000 individuals occupy these vulnerable areas. This study highlights the importance of comprehending the causes and ramifications of landslides through field surveys, questionnaire surveys and database analysis derived from literature reviews. The findings of this study will facilitate the identification of the problem and the development of remedial measures for landslide mitigation in Chattogram City.

Aims and Objectives

The study assesses the landslide vulnerability of hill inhabitants in CMA and explores mitigation strategies to reduce risk in Chittagong City. Objectives include evaluating vulnerability and identifying a sustainable strategy to minimise risk. The specific objectives of the study are:

1. To study and observe existing land use in the hills by identifying potential landslide-vulnerable hilly areas in Chattagram City.
2. To identify the proven causes of landslide incidents in CMA.
3. To explore sustainable approaches to reduce landslide risk in CMA.

Material and Methods

For the study, both qualitative and quantitative approaches were considered. To accomplish the research, the following steps are followed:

Research through study area analysis: The case study method helps to understand issues in depth and presents a real-world situation regarding the impact and consequences of hazards. This study uses the case study approach to examine the landslide hazard in CMA.

a. **Selection of the Study area:** To achieve a comprehensive outcome, several areas were surveyed. Hilly locations were selected for the preliminary study through physical and literature surveys. The study area was chosen based on settlement vulnerability, population density and socio-economic conditions. Vulnerable areas to landslides in CMA included Batali hill, Motijharna, Labubagan, Kusumbug residential area, Khulshi and Bayazid Bostami. Among these, Batali hill and Motijharna are the most densely populated and at greatest risk, with numerous historical landslide incidents. Thus, these areas were selected as case study regions for the research.

Analysis of historical landslide events in CMA

a. A database on past landslides in CMA has been created to analyze their intensity, causes and impacts. Information was gathered from newspapers, journal articles and various organizations' websites. A reconnaissance survey was conducted to collect additional data for the research.
b. **Reconnaissance survey:** A reconnaissance survey was conducted in selected locations, including case study sites. Information gathered from various organizations during the survey led to a list of vulnerable hills and nearby settlements. The Chattagram Development Authority (CDA), Chattagram City Corporation (CCC), Department of Environment (DoE) and key members of the Hill Management Committee participated in the survey.
c. **Field Survey:** After the reconnaissance survey, a detailed field survey was conducted to make the inventory in two selected areas. During the field survey, information regarding the landslide incidents and their causes and consequences, perceived and observed by the local people, has been collected.

Accumulating Data of Landslide Areas: The landslide database was created using primary and secondary data. A household survey and focus group discussions gathered primary data, while CDA, CCC, DoE and the Department of Disaster Management provided secondary data. An extensive literature review collected additional information. All data related to the landslide areas were analyzed using statistical software like MS Excel and SPSS.

Landslide vulnerability in Chittagong City

Rapid urbanization in Chattagram City creates problems like haphazard development and extensive migration, leading to increased urban poverty and forcing disadvantaged people to live in slums and hazard-prone areas (such as hill slopes). Unplanned development is rapidly transforming hilly areas into hazardous settlements to accommodate urban migrants near their workplaces with low rent. Consequently, numerous fatal landslides have occurred annually in the city for decades.

History of Landslides in Chattagram City: During the monsoon season, landslides frequently occur in Chattagram. In recent years, CMA has faced 12 significant events, the worst being in 2007 and 2017. Factors include illegal hill cutting, altered slopes, unauthorized settlements and poor infrastructure. Natural causes like heavy rainfall and soil composition also trigger landslides.

On June 11, 2007, 8 days of rain (610mm) led to landslides that killed 128 people. On June 26, 2012, another landslide from 8 days of heavy rain (889mm) occurred. A flash flood landslide in Lalkhan bazar on July 19, 2015, killed 3. On June 13, 2017, landslides in Chattagram division resulted in 160 deaths and the destruction of many settlements. Minor landslides each rainy season also cause significant damage. Addressing landslide risks is crucial for the safety of residents and ecological restoration in Chattagram city.

Areas which are vulnerable to landslide in CMA: Landslides were not prioritized by policymakers in Bangladesh until the twentieth-century disasters. After the 2007 landslide, the Department of Disaster Management (DDM) acknowledged its severity in CMA and classified it as a national disaster. In a SAARC workshop in Bhutan, Mahmud and Khan presented a map of landslide-prone areas in Chattagram, which the Disaster Management Committee later adopted to address CMA's landslides.

CMA was categorized into high, moderate and low-risk areas. Researchers[21,22,24] identified Lebubagan, Bayazid Bostami, Kushumbug, Batali Hill and Motijharna as high risk, Foy's Lake and Khulshi as moderate risk and Nairabad and Golphar slum as low risk. Notably, Lebubagan, Batali Hill, Kushumbug and Motijharna suffered severe damage in the 2007 landslide and are highly populated, often impacted by landslide hazards each rainy season.

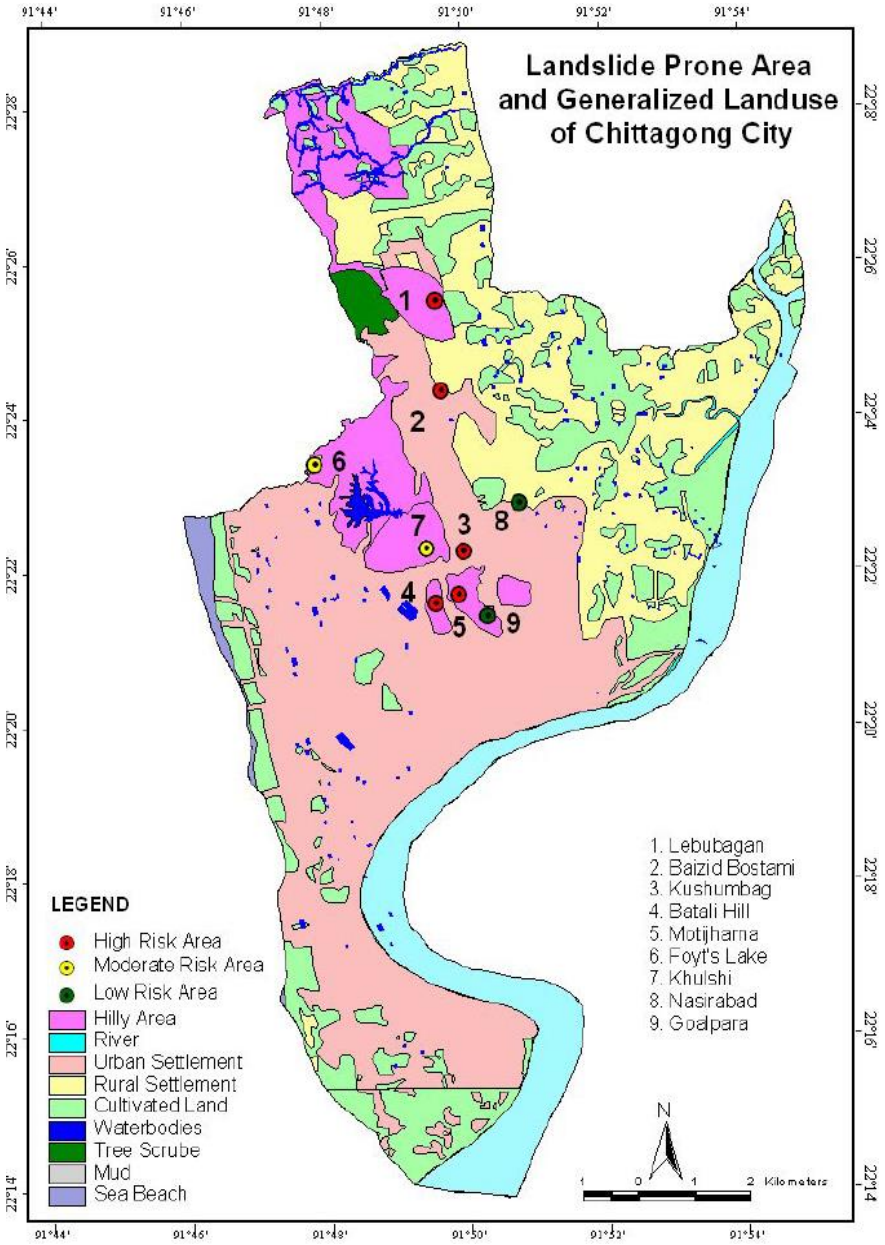

Figure 1: Landslide-prone areas in Chattagram City[21,22,24]

Study area profile

After reviewing factors related to the landslide, Batali Hill and Motijharna within CMA were selected for the study. These areas were the most affected during the 2007 landslide events and were identified as highly vulnerable. Both are located in the city core and are densely populated. Most settlements in Batali Hill and Motijharna are illegal, built on hilltops or around the hill toe, altering the natural slope and landscape.

Over the last 25 years, proximity to the city center, convenience to workplaces, low rents and insufficient authority oversight attracted illegal settlers who built and rented these areas to low-income individuals.

Batali Hill: Batali Hill, the highest peak in CMA at about 280 feet, is a popular tourist spot. It is located near the city centre, adjacent to Tiger-Pass and has a high population density, primarily consisting of low-income migrants. The residents work as rickshaw pullers, factory workers, maids, porters, beggars, cleaners, street vendors, salespeople and shopkeepers. This settlement is known for easy access to workplaces. Influential individuals constructed these illegal settlements in collusion with corrupt government employees. The hill is poorly maintained and monitored by authorities.

Batali hill settlements are densely clustered, with houses made of bamboo, tin and other fragile materials. These settlements severely disrupt the hill slope and land cover. Hill cutting and vegetation loss have damaged Batali Hill's ecosystem. The natural drainage system of the hill is obstructed, causing water to stagnate during heavy rain, saturating the soil and increasing the risk of erosion and landslides.

Land Slide History: Batali hill area experienced numerous landslide incidents in previous years. Among them, the incidents in 2011 and 2015 were the most devastating.

Landslide of July 1, 2011: On July 1, 2011, a landslide in the Tiger Pass area killed 17 people after a hill protection wall collapsed in Batali hill during the early morning. Victims unable to find shelter were buried in their tin-roofed slum houses at the hill's base. The wall, built by CCC to prevent soil erosion, was structurally unsound and lacked weep holes for rainwater runoff, leading to its collapse.

Landslide history of July 20 2015: On July 20, 2015, heavy rainfall triggered landslides in Bayezid, Khulshi and Lalkhan bazaar, resulting in six deaths, including five children and a woman. In Lalkhan bazaar, a wall collapsed on the house of 30-year-old Moriam Begum, killing her and her two children, 2-year-old Suraia and 5-year-old Akhi. This tragedy marked another deadly wall collapse following the 2011 incident, attributed to illegal land encroachment, hill cutting and administrative negligence.

Motijharna Area: Motijharna, near Batali hill, is the largest informal settlement in the Chattagram valley. On June 11, 2007, a major landslide disrupted the settlement and CMA areas. Like Batali hill, Motijharna has a dense population of informal and illegal settlements. Most residents are landless migrants drawn by urban job opportunities. The area primarily houses factory workers, rickshaw pullers, CNG drivers, housemaids, garment workers, vendors and drug dealers.

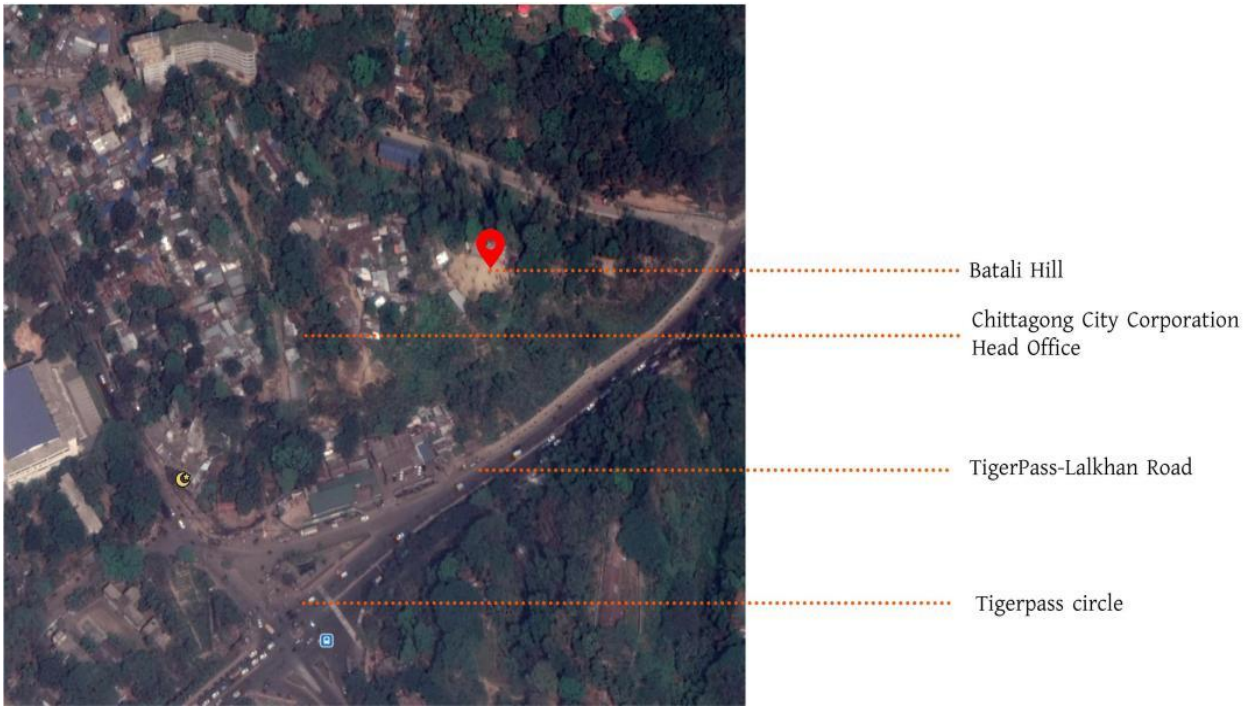

Figure 2: Google image Batali Hill

Figure 3: The images of Batali Hill area.

Figure 4: Google Image Motijharna area

Landslide History: Landslides in Motijharna are common during the rainy season. However, major landslides occurred in 2013, 2007, 1996, 1994, 1991 and 1982, causing significant casualties and property damage, severely disrupting the ecosystem. It is sorrowful that many settlements remain on the hilltop and downslope. The sandy soil of Motijharna hill has become increasingly steep in recent years, nearing vertical.

Landslide of June 11, 2007: In June 2007, it rained for eight days, with 267 mm recorded on June 11. Waterlogging submerged several ground floors. A severe landslide in Chattagram, the deadliest in Bangladesh's history, buried families while they slept due to loose soil and heavy rain. Mud and water swept through settlements, affecting 2072 families and causing at least 127 deaths. The Motijharna of Lalkhan Bazar and Goribullah Shah Mazar were severely impacted, along with locations like Lebu Bagan, Chattagram Cantonment, Kaichaghona, Sekandar Colony, Taragate, Bayezid and parts of Chattagram University Devpahar under Kotowali and Panchlaish Thana.

Landslide of August 18, 2008: Another incident occurred in CMA in 2008. This landslide impacted the Motijharna area, resulting in 11 bodies found under the mud. A rain-induced mudslide struck early on August 18, affecting 14 illegally built houses on the hillside.

Figure 5: The images of Motijharna area. Source: Author

A massive chunk of mud from Tankir Pahar swept down due to heavy rain onto the tin-roofed homes. The incident happened around 5:00 am. while residents were sleeping, leading to the deaths of 11 people, including six from one family. Firefighters, assisted by locals, rescued survivors and recovered the bodies.

Landslide of July 28, 2013: A landslide struck Akbar's colony at Tankir Pahar on July 28, 2013, an illegal settlement. Another landslide in 1995 killed four people in the same area. On that day, heavy rain saturated the soil, triggering a mudslide that hit a house below. A mother and daughter working at Four H Garments Industry died when the 20-foot-wide mudslide buried their small tin-roofed hut. Despite knowing the risks, they chose to live there for easy access to work and low rent.

Field Survey and Respondents' Opinion: For the field study, these two landslide-prone areas in the Chittagong Metropolitan Area were chosen for physical and questionnaire surveys. The area's respondents were cooperative while surveying and had some knowledge of landslides. The respondents found that the informal settlements in the study areas are famous among low-income people because they are close to the CBD and the house rent is low in these areas.

Respondents' Demographic Profile: A questionnaire survey of 210 families was conducted randomly during the field study. Among 210 respondents, male participants (58%) dominate in number and most of the respondents (76.80%) are in the age range of 15-55 years. The respondents are mainly from Bangladesh's Chattagram, Comilla, Feni and Noakhali districts. The leading cause of migration is for better employment opportunities. The maximum number of respondents residing in this area is about 10 to 30 years, whereas only a few have lived here for more than 60 years.

Education: The education level of the respondents is very low. Most of the people in the study area are illiterate and there is a lack of educational institutions in the area. 48% of the total respondents' children do not go to school. Recently, some NGOs (like Jago Foundation) opened primary schools in the study area.

Economic Activities: Most of the respondents are involved in informal economic activities and a vast number are unemployed. Their primary occupations are garment workers, daily labourers, rickshaw pullers, van drivers, small business drivers, housemaids etc. People living in the study area mainly migrated from various locations to the study areas for better lives and livelihoods. Most of the respondents' workplaces are within or around the study area. According to their information, they do not have any savings that may work as a safety net after any hazard or emergency.

Housing status of the households: The quality of houses in the study area is inferior. Most of the houses in the study areas are semi-pucca. Common construction materials used to build homes are 5" brick walls, wood and bamboo and roofs are made of tin or thatch. A few multistoried buildings also exist in the area. Single-room houses are most desirable in the study areas. The average size of the room is 100-120 sqft.

Perception about landslide incident: Most respondents expressed concern about landslides and shared their perceptions of the causes and timing. They suggest strategies to reduce vulnerability. Although they receive early warnings, many tend to ignore them. The Chittagong City Corporation is responsible for disseminating these warnings. Relocating from landslide-prone areas is the most effective solution but most respondents are unwilling to move due to affordability issues, such as house rent and work distance.

Situation after landslide incident: A landslide disrupted the lives and livelihoods of respondents. Many died and properties were damaged. Respondents reported minimal assistance from authorities. The CDA and CCCA primarily assist the affected people. Several issues must be resolved to reduce landslides including hill cutting, deforestation, afforestation and planned settlements on hills. Multiple authorities, including the CDA, CCCA, public administration, NGOs and civil societies, are responsible for addressing these issues.

Focus Group Discussion (FGD): Focus group discussions in the study area involved 5-7 long-term residents experienced with landslides, alongside representatives from local administration, households, teachers and Ansar

members. They addressed 15-20 questions about landslides, categorized into four areas: general perception, causes, impact on life and management. The discussions revealed gaps between local perceptions and formal organizations about landslide causes and effects, with participants sharing potential mitigation ideas for hills.

General perception of landslide: All the focus group discussion participants have been living in the study area for a long time. They have a basic idea about the landslide incidents in the study area. Participants identified the vulnerable location of the landslide. They perceive the landslide time and can relate rainfall intensity with the landslide.

The reason behind the landslide: Participants identified several reasons for the landslide. According to their experience, landslide intensity and magnitude are increasing because of unplanned settlement, hill cutting, excessive rainfall and improper land management. They also identified some reasons behind living in the study area, even in risky conditions. Human activities are the main reason behind the increasing number of landslide incidents. Hill cutting without considering slope stability makes the hills more vulnerable to landslides.

Management of landslide: Participants proposed ideas for managing landslides and identified anomalies in current practices. They suggested improvements for effective management to reduce landslides. Landslide management has struggled due to discrepancies among authority activities. Synchronizing efforts and ensuring genuine participation can mitigate incidents. Many participants blamed political figures, corrupt officials and local influencers for illegal hill management activities. Consequently, efforts to reduce landslide impacts have largely been ineffective. Participants gave several suggestions to reduce the adverse effects of landslides. Relocating to other safer places and avoiding settlement in hill toes are the most effective solutions. Participants also suggested avoiding deforestation and hill cutting. To relocate the affected people to other areas, proper rehabilitation including allocating Government land and providing jobs, must be done.

Causes of landslide

The leading cause of the Chattagram landslide is heavy rainfall. The quality of the sandy and muddy soil can collapse easily during rain. Hill cutting and vegetation loss further contribute to landslides in CMA. In 2005, the Ministry of Environment and Forest and CDA restricted hill cutting to protect natural settings. However, continued insufficient monitoring allows it to persist. Landslides lead to deaths, property damage and ecological disruption, emphasizing the need for sustainable solutions. Immediate actions must be taken to tackle the causes of landslides in CMA.

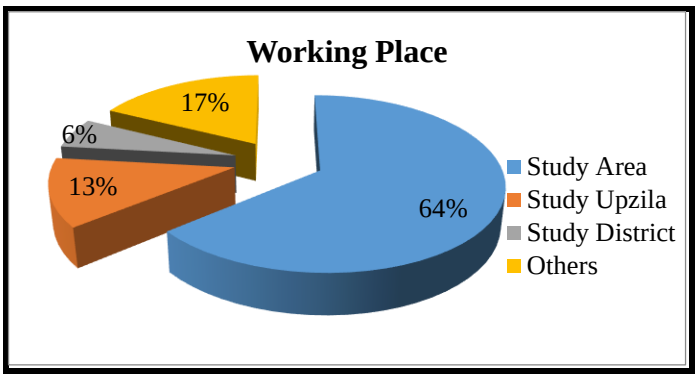

Figure 6: Workplace of the respondents

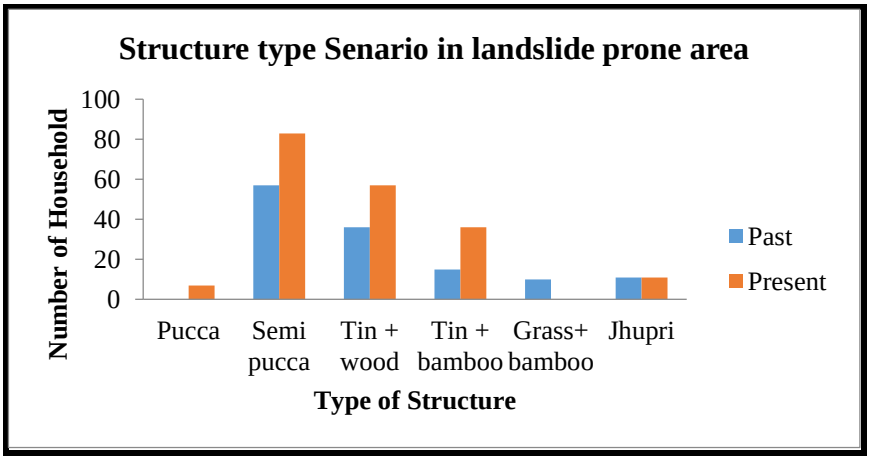

Figure 7: Structure and construction materials of Houses

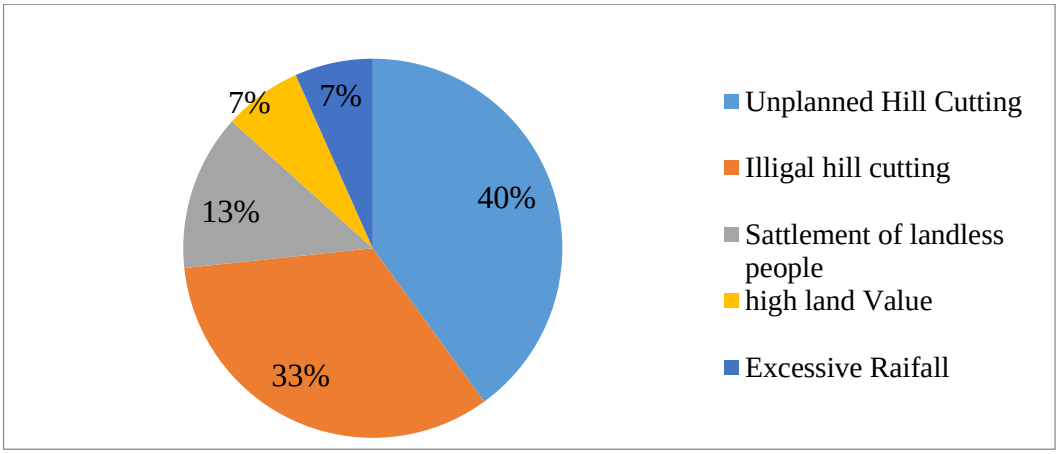

Figure 8: Reason behind increasing Landslide incident

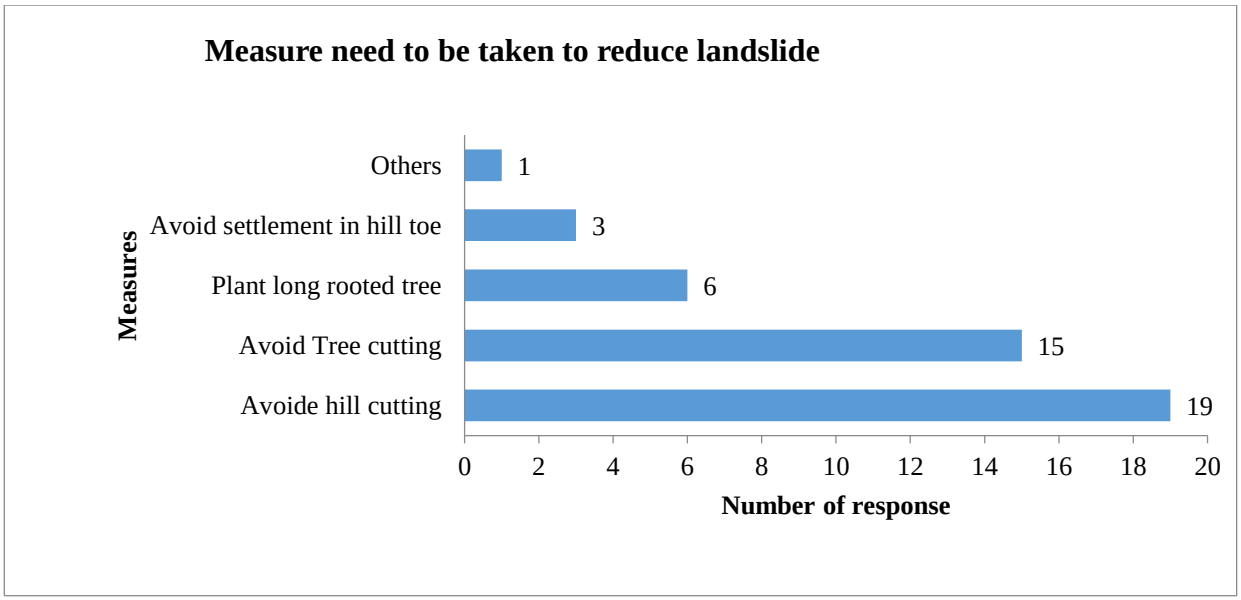

Figure 9: Way to reduce landslide.

Causes of Landslide in CMA: Causes of landslides can be divided into two categories: 1. Natural causes and 2. Anthropogenic causes. These two factors triggered the combined landslide in CMA.

Natural causes of landslide in CMA: Landslides in hilly areas are influenced by their' steepness, soil properties, morphology of terraces and vegetation on the hills etc. These hills' characteristics associated with heavy rain are responsible for the hills' landslide. The intensity of the landslide depends on this natural phenomenon of the hills. The primary natural causes of landslides are as follows:

Soil character and landslide: Soil characteristics on hills significantly influence landslide events. Hill slope stability depends on soil density, shear strength, moisture content, clay minerals, particle size and distribution. Chattagram City's sandy and muddy soil erodes easily during heavy rain due to hill cutting or land cover changes. Eroded soil flows down, blocking natural drainage, causing water to stagnate and saturate the soil. This saturation reduces the soil's compactness and leads to mineral dissolution. Sandy soil washes away easily, while muddy soil absorbs water and becomes heavy. The weight of this saturated, muddy soil causes the hill to collapse, resulting in landslides.

Slope stability problem in the hill: Landslides depend on hill slope steepness. Steeper slopes allow more effortless soil movement, while gentler slopes hinder it. Human intervention alters slopes, making them unstable. The hills of Chattagram are part of the tertiary hills and have weak, unstable soil. Batali and Motijharna hills are steep enough to influence landslides. Human actions make these hills near vertical, increasing landslide vulnerability. The study found that hill slopes in Chattagram City, where frequent landslides occur, range from 30 to 40 degrees.

Rainfall: Landslides in Chattagram city are closely linked to rainfall. Heavy rainfall has been a significant cause of previous landslides in CMA. Prolonged heavy rainfall saturates the soil, causing it to lose compactness. This loose soil then separates from the hill and shifts. CMA receives more rainfall than other regions in Bangladesh, averaging 300mm annually, with maximum precipitation in June, when

most significant landslides occur. Continuous rain over several days from cyclones or sea depressions can also trigger landslides in CMA.

Human intervention in Hill and Landslide in CMA: Most of the landslides in CMA happened in those areas where human intervention took place. A human intervention like hill cutting, an unplanned and illegal settlement in the hills, blockage of natural drainage systems through road construction, industry and housing and deforestation fuel landslide events. The major human interventions which triggered the landslides in CMA are as follows:

Hill cutting: Hill cutting for land development, housing and infrastructure in Chattagram city is common. Rapid urbanization in CMA attracts many migrants, mostly from lower-income groups, who want to live near their workplaces for low rent. Some influential individuals illegally occupy Government hills near the city center, such as Batali hill and Motijharna hill, to build illegal settlements on slopes or at the base.

Deforestation: Trees and shrubs reduce landslide risk by stabilizing soils and preventing erosion. Deforestation exposes soil, increasing vulnerability, especially during heavy rain. Vegetation helps to absorb water, lowering saturation levels. The deep roots of large trees further anchor the soil. In Chattagram city, many hills suffer from deforestation. Surveys and historical data reveal that past landslides primarily occurred in severely deforested areas like Khulshi, Batali Hill and Kusumbug.

Unplanned and illegal establishment of settlement: As described earlier, massive migration occurred in Chattagram city because of its rapid urbanization. With this rapid urbanization, many illegal and unplanned settlements were built in illegally occupied hilly areas. The poor migrants choose this settlement because it is near the workplace and the house rent is low. To construct this settlement, the builder changes the hill slopes drastically by cutting the hills through deforestation.

Most of these settlements are situated on hill top, hill slope and at the hill toe at a risky position. The migrants here migrated from Cumilla, Noakhali, Barishal, Khulna etc. which are geographically plain land. They do not know about living in the hilly areas and are not habituated to the local ecological system in the hills. So, they also disrupted the hills' ecology and destroyed the hills' natural slope. Thus, the settlements on the mountain increase the vulnerability of landslides.

Improper Drainage System in Hill: The natural drainage system is disrupted by unplanned settlement on the slope of a hill. People cut trees to clear hills for housing purposes. Trees are uprooted and so the soil gets loosened. During the rainy season, the top soils of hills are washed out and obstruct natural drainage systems.

Figure 10: Landslides happen due to the destruction of a hill foot.

Figure 11: Landslides happen due to hill cutting for construction purposes

Figure 12: Prevention measure through engineered and local methods.

Remedial safety measures to mitigate landslide hazard

The national authority took landslide incidents seriously after the 2007 disaster. The Divisional Commissioner of Chattagram was instructed to investigate. A technical committee of various government and non-government agencies, researchers and engineers then assessed the situation and proposed measures to reduce landslides in CMA. The committee suggested an integrated policy for managing landslides, including urban planning and effective regulation enforcement to protect city hills. While landslides cannot be prevented entirely, their impact, intensity and frequency can be reduced by following these measures:

Mitigation measures to reduce landslide: The vulnerability of landslides cannot be prevented entirely because of the natural setting of the hills in Chattagram such as physiography, land formation, rainfall etc. However, its impact might be reduced by implementing minimum human intervention in the landslide-prone hills. To get sustainable solutions, the following mitigation measures should be initiated.

Preparing Landslide Inventory: To manage landslides sustainably, an inventory of all locations must be created. This inventory should include landslide intensity, dimensions, impacts, causes and primary triggers. Based on this, a vulnerability assessment report must be prepared, allowing the CMA to be demarcated into different vulnerable zones. An in-depth survey (geological, ecological and socioeconomic) of these zones is essential to understand the hills' characteristics and guide necessary mitigation strategies.

Re-location of the foothill slums: Illegal settlement in the hilly area has to be restricted and people already living in the risky hilly area should be relocated and rehabilitated. Any settlement on the hilltop, on the hill slope, or at the hill toe must be restricted. The existing settlement must be demolished and the inhabitants should be relocated to a safer place following proper rehabilitation procedures with livelihood opportunities.

Protection by stopping hill-cutting: Landslides in CMA can be significantly reduced by prohibiting hill-cutting in the city. Regardless of authority, unauthorized and unplanned hill-cutting must be banned and those involved should face punishment. Permission for brick fields within 10 km of hilly areas and housing projects within 5 km should be restricted. City expansion should move towards the Karnafuly river instead of the northern hilly region. A Committee under the Hill Management Act must assess hill-cutting. Safety precautions, like retaining walls, should be implemented when hill slopes or toes are damaged.

Developing an efficient early warning system: There is a relationship between the rainfall and the landslide. From the database of previous landslides, it can be simulated. This simulated correlation can help to develop a warning system. To do this, real-time monitoring is necessary. An efficient early warning system can be created based on that monitoring and simulation model. This early warning should be disseminated effectively and adequately.

Implementation of laws and monitoring of hill management plan: The existing law and legislation regarding landslide management must be analyzed and modified more effectively. There are rules regarding hill cutting in the city, as implied by DoE, CDA, CCC and other authorities, but those rules have not been implemented or monitored effectively. As a result, some influential people take the opportunity to break the law. So, more specific and strict hill management laws and policies should be improvised as soon as possible and those laws must be implemented and monitored correctly.

Technical measures for protecting against landslides: Landslides in CMA cannot be entirely prevented, but mitigation measures may reduce their occurrence and impacts. Preventive techniques should be implemented in prone areas, such as retaining walls, deep-rooted trees, improved drainage systems, slope stabilization (using erosion-controlled blankets, geo-cell fencing) and flexible debris barriers. Awareness is also crucial for residents in landslide-prone areas. They must understand the risks,

causes, consequences and hill ecosystems. Establishing training programs for sustainable hill management is essential. Additionally, collaboration among organizations like DoE, CDA, CCC and government and non-government agencies is vital in reducing landslide vulnerability in CMA.

Conclusion

This study aims to identify the causes and consequences of landslides in the CMA study area. The findings reveal that landslides disproportionately affect low-income people and are neglected at the national policy-making level. From an environmental perspective, they are considered devastating events that disrupt the ecosystem in Chattagram city. This research on landslides discusses some sustainable mitigation measures for effective hill management in the study area. Before the disastrous landslide of 2007, there was no proper hill management policy in CMA, resulting in haphazard settlements on risky hill slopes and severe destruction of hills due to land cover changes in CMA.

Until that severe incident, national policymakers focused only on hill cutting without integrated management considering local contexts. Consequently, influential individuals illegally occupied many hills in CMA (owned mainly by Bangladesh Railway) and established slums on hill slopes for urban poor residents. After 2007, the "Chattagram Hill Management Committee" was formed to save the hills through proper management and reduce landslide vulnerability in CMA. For effective, efficient and sustainable approaches, all stakeholders in hill management should work in an integrated and comprehensive manner through coordination among all agencies.

Local people should be involved in policy-making and should be made aware of landslide issues. The study provides references to assist local and national policymakers in preparing guidelines to mitigate landslides in CMA. The research will also help to identify major factors behind previous and potential future landslide events to create a susceptibility map of risky areas, facilitating emergency decision-making and efficient rescue and evacuation strategies during landslide events in CMA.

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